Parametric Detector Design Tool

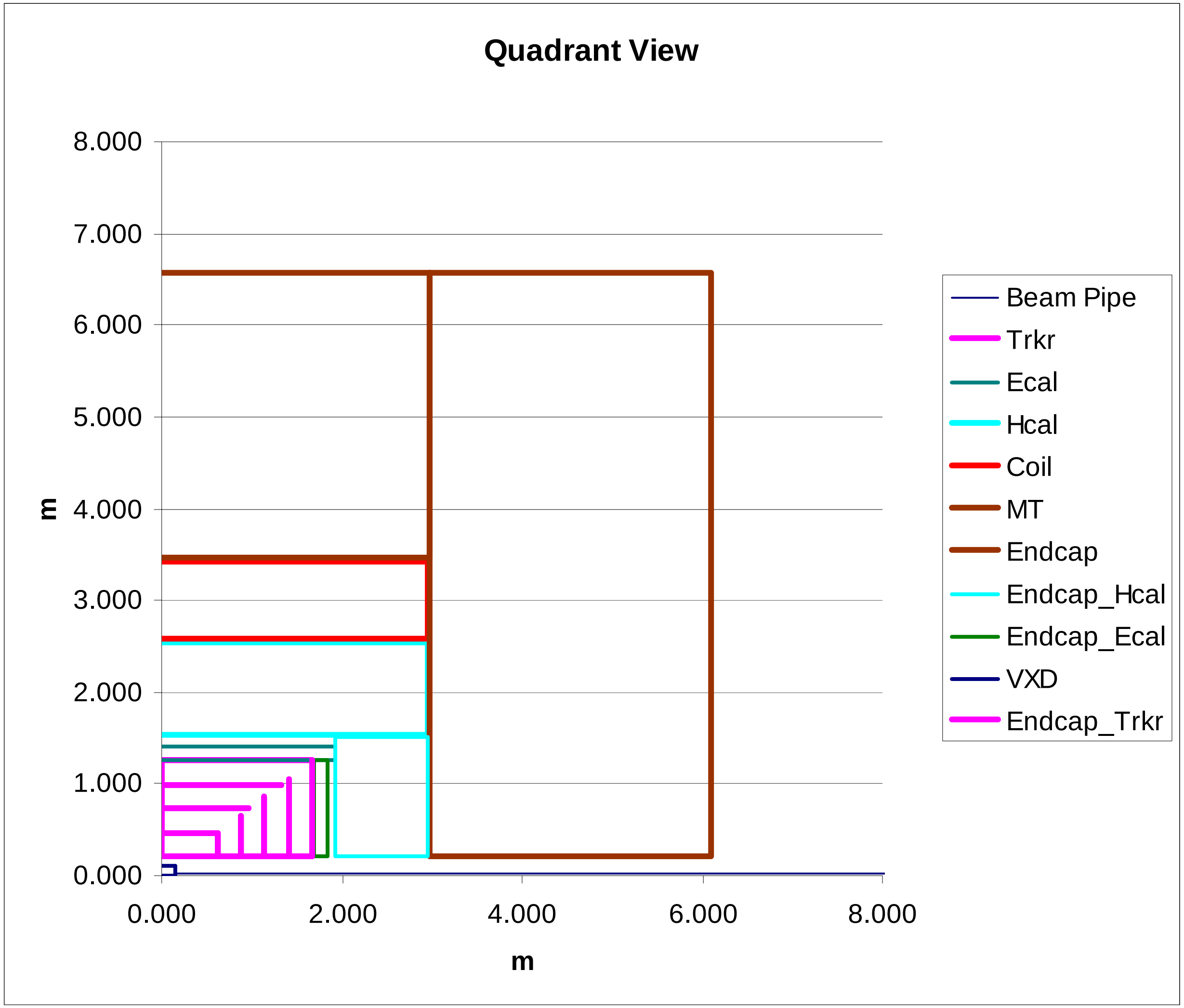
	Simple Minded Parametric Detector Comparisons							
Tracking					Stored	Flux inside	Return DR	ID
Radius	Field	E Flow	R_Coil (middle)	1/2 length to endcap iron	Energy		m of Fe	
R (meters)	B (Tesla)	BR^2/Rm				Tm^2		
					Megajoules			
0.75	6	1.9	1.25	2.7	372.7	29.5	1.0	Small
1.5	3	2.4	2.05	4.3	401.9	39.6	1.0	Precise
2	3	4.3	4.05	4.7	1734.6	154.6	2.3	Large
1.25	5	4.3	2.78	2.9	1400.8	121.4	2.3	Silicon
1.6	4	5.7	3.4	5.3	2427.6	145.3	2.4	Tesla

Simple Excel program evolved to tool to help your intuition. Lots of parameters to play with, instant gratification.

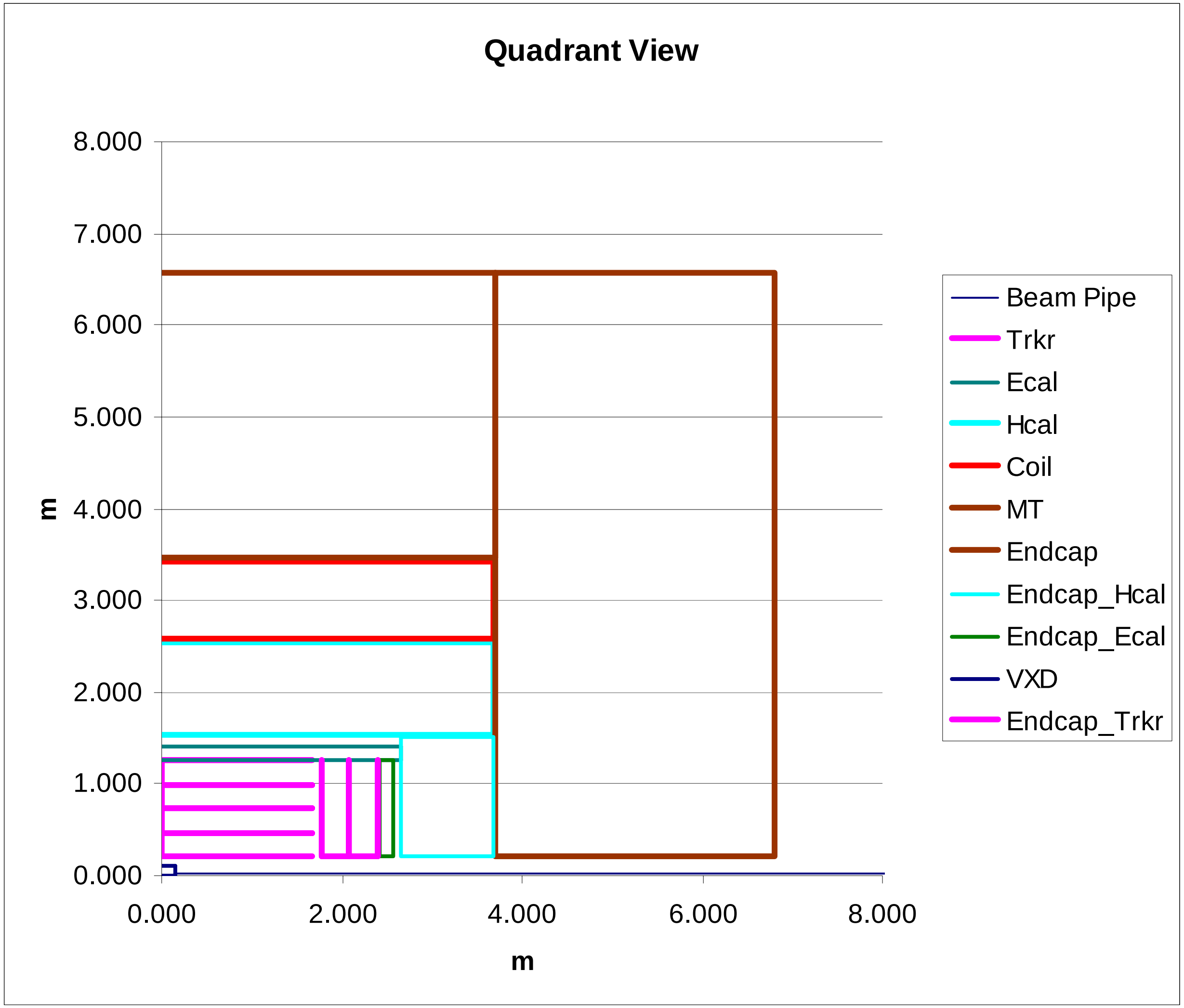
Major Issues

- *Assume* Energy Flow Calorimetry is necessary
  - High density Silicon-Tungsten EMCal
- Understand and control costs
- No compromise on high momentum tracking
  - Silicon strips for robustness; high resolution
  - Shape of tracker
- High field for:
  - BR^2 for energy flow
  - Br^2 for tracking resolution
  - "Cleanup" for VXD
- Hcal location – inside or outside coil

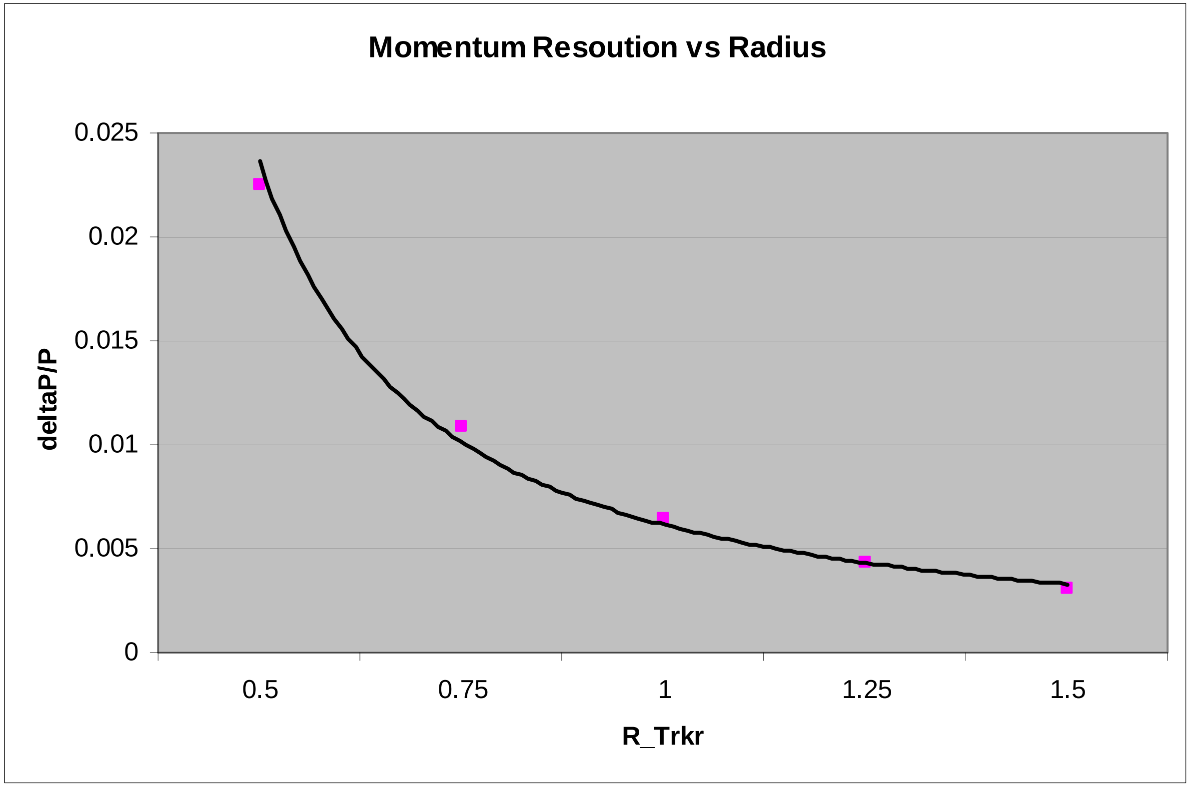
Baseline SD Design



Tracker “Box” Format

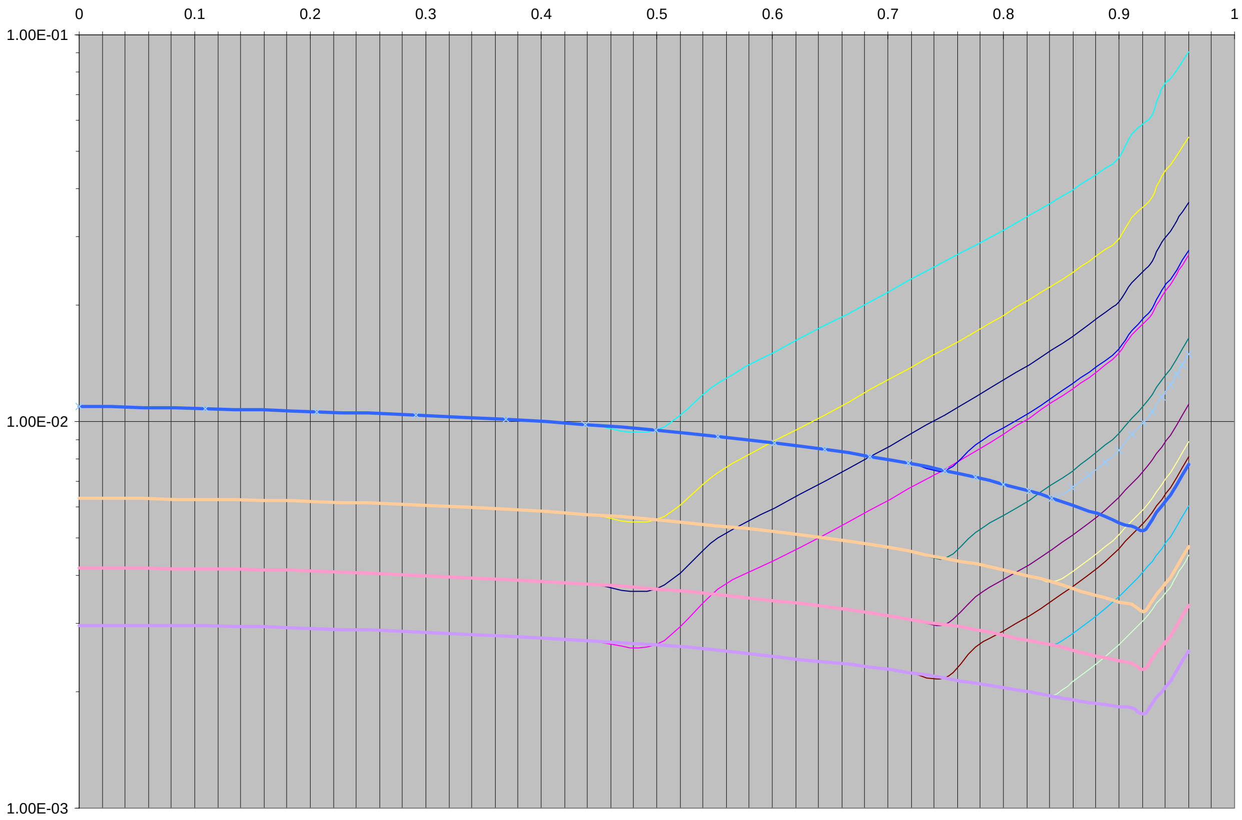


ΔP/P vs R_Trkr



Momentum Resoution vs Radius
0.025
0.02
0.015
0.01
0.005
0
deltaP/P
0.5
0.75
1
1.25
1.5
R_Trkr

ΔP/P vs Cosθ



Curve families correspond to R_Trkr of 0.75,1.0,1.25, and 1.5 m. Breaks correspond to $\cos\theta_{max}$ of 0.5,0.75,0.85, and 0.92.

Tracker

- Tracker shape: Box design probably more realistic. Adopted by ATLAS after trying other formats. Resolution not yet calculated!
- End structure thin, so endcap tracker viable.
- Effects of multiple scattering not yet evaluated for physics.
- Track finding not yet simulated. Should be fine for stable tracks. (5 Layer VXD) Decays would need help from the tracking calorimeter.
- Detectors at least 10cm square (Now being produced by Hammamatsu for GLAST).
- Barrel readout at ends of each layer, with minimal material by using ASIC's.
  - Duty factor of few μs every 8 ms. Tiny compared to ATLAS. Thermal management should be easy.

EMCal

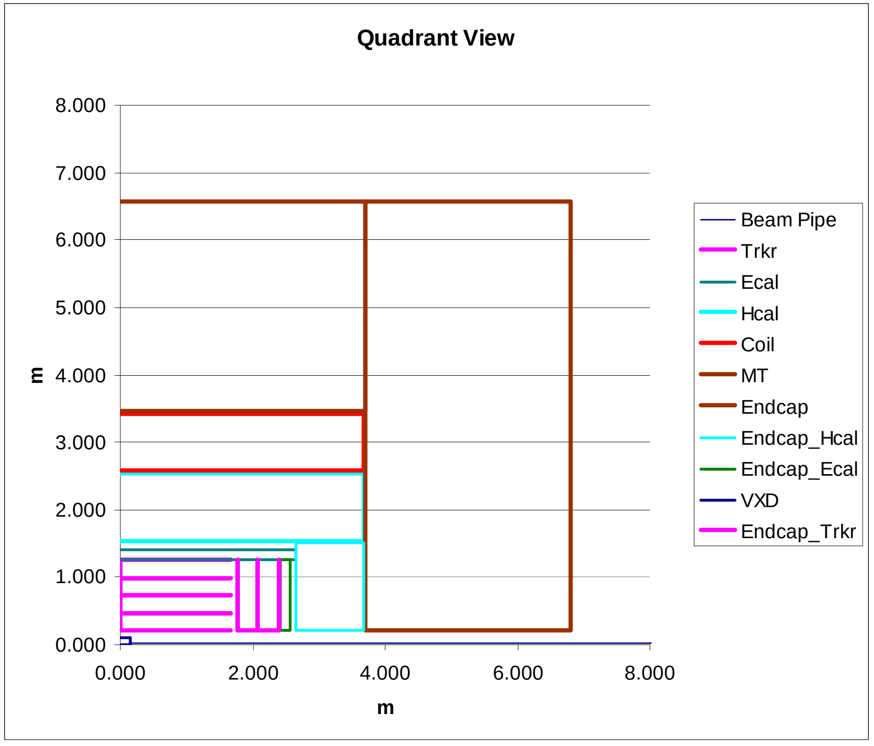
EMCal		
W Thickness	2.5	mm
Gap	2.5	mm
Layers	30	
Total X0	21.43	

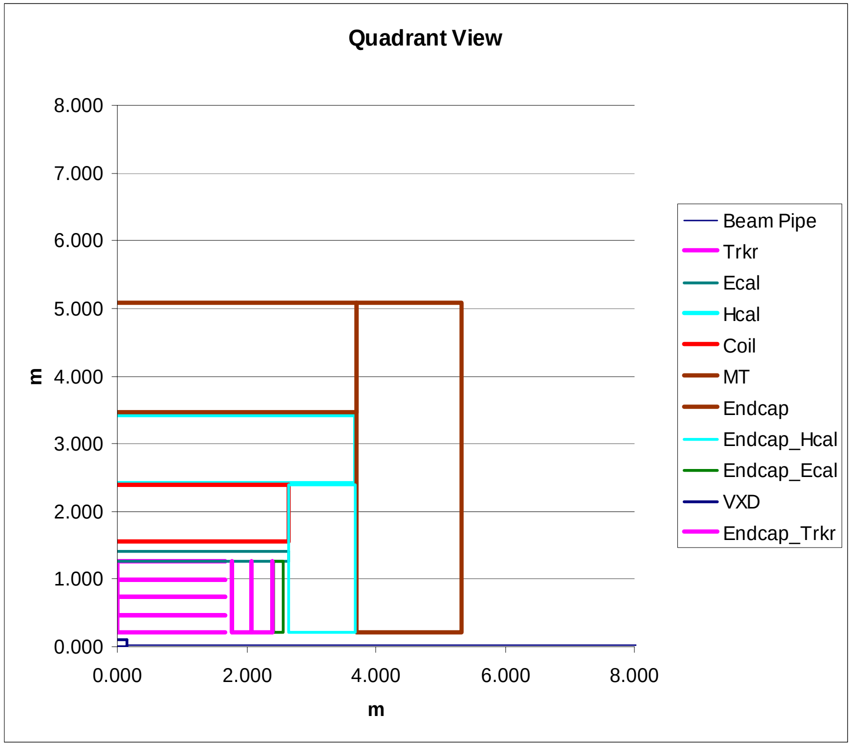
- Layers of tungsten with gaps for arrays of Si diodes mounted on G10 motherboards
- Gap thickness is major issue; determines Moliere radius and performance of Energy Flow calorimetry.
    - 4 mm seems easy – accommodate 0.3-0.5 mm Si, 2 mm substrate, 1.5 mm clearance
    - 1.5 mm barely plausible, probably stacked assembly with buttons rather than insertion.
    - For now, assume 2.5 mm gap and think!

EMCal, continued

- Diode pixels between 5 – 10 mm square on largest hexagon fitting in largest available wafer. (6" available now)
- Develop readout electronics of preamplification through digitization, zero suppression, optical fiber drive integrated on wafer. Fallback is separate chip diffusion or bump bonded to detector wafer. (R&D opportunity!)
- Optimize shaping time for small diode capacitance. Probably too long for significant bunch localization within train.

Hcal Location Comparison

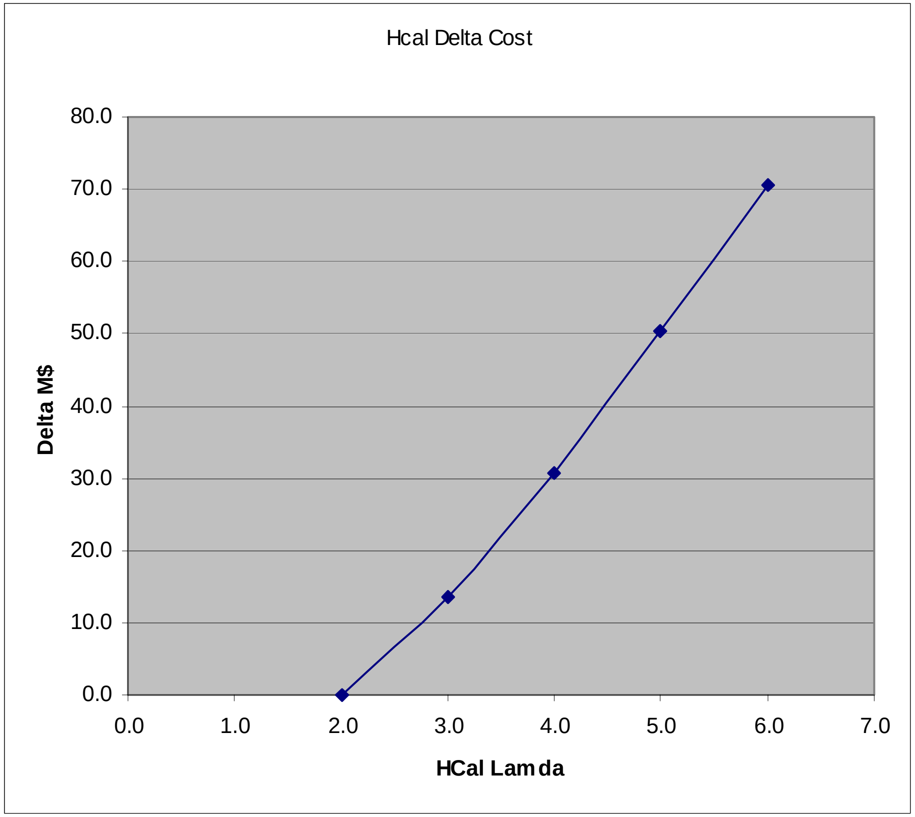




HCal

- Hcal assumed to be 4 λ thick, with 34 layers 2 cm thick alternating with 1 cm gaps.
- Could use “digital” detectors, eg high reliability RPC’s
- Hcal radiator non-magnetic metal – probably copper or stainless
  - Tungsten too expensive
  - Lead possible, but mechanically more painful.
- Hcal thickness important cost driver, even though Hcal cost small.

SD Δcost vs Hcal thickness



Metal Costs

	Metals Table					
Metal	*unit*	W	Stainless	Pb	Cu	A36
X_0	m	0.0035	0.0176	0.0056	0.0143	
Lamda_I	gm/cm^2	185	131.9	194	134.9	131.9
ρ	gm/cm^3	19.3	7.87	11.35	8.96	7.87
Lamda_m	m	0.095855	0.167598	0.170925	0.150558	0.167598
Cost	$/kg	100	2.75	1.43	4.2	3.48
Metal Notes:						
	W is Hevi-met; 95% tungsten; 2"plate					
	Stainless is non magnetic stainless steel; 2" plate					
	Pb is antimony or dispersion strength lead; 2" plate					
	A36 is medium grade low cost magnet steel, fabricated for magnet					

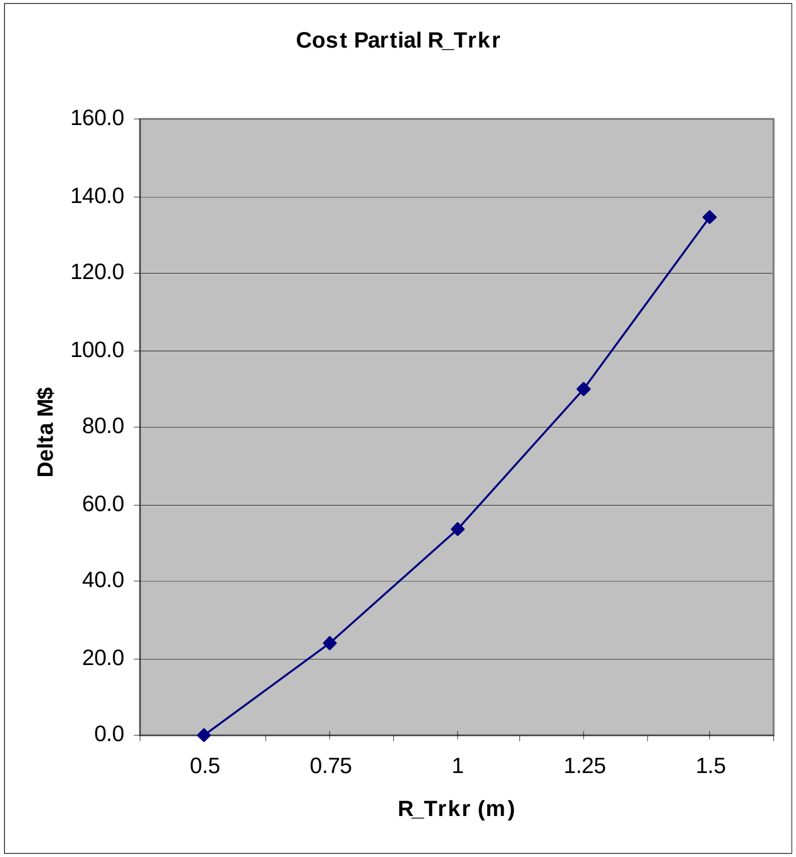
Cost Driver Estimation

Cost Driver Estimation				
item	*n*	*unit*	*unit cost*	*total*
Trkr Si	73.3	m^2	100000	$7,330,383
Trkr Electronics	3036.9	ea	580	$1,761,386
Trkr Si EC	47.8	m^2	100000	$4,783,075
Trkr Electronics EC	5236.0	ea	580	$3,036,873
EM Cal si	1343.3	m^2	30000	$40,299,455
Em Cal si endcap	294.1	m^2	30000	$8,822,865
EM Cal W	64815.0	kg	100	$6,481,496
EM Cal W endcaps	14190.1	kg	100	$1,419,011
HCAL Rad	5.04E+05	kg	2.8	$1,387,109
HCAL Rad endcap	7.74E+04	kg	2.8	$212,762
Coil	2083.5	MJ	19925	$41,513,541
Fe	4.40E+06	kg	3.48	$15,307,395
Fe endcap	5.6E+06	kg	3.48	$19,353,413
Fe additional (1)	1.49E+06	kg	3.48	$5,199,121
Total (M$)				$156.91
Notes:				
1. Assume 15% additional magnet iron for support, transport, etc				
2. Only tracker electronics costs included (yet)				
3. No approximately fixed cost included				

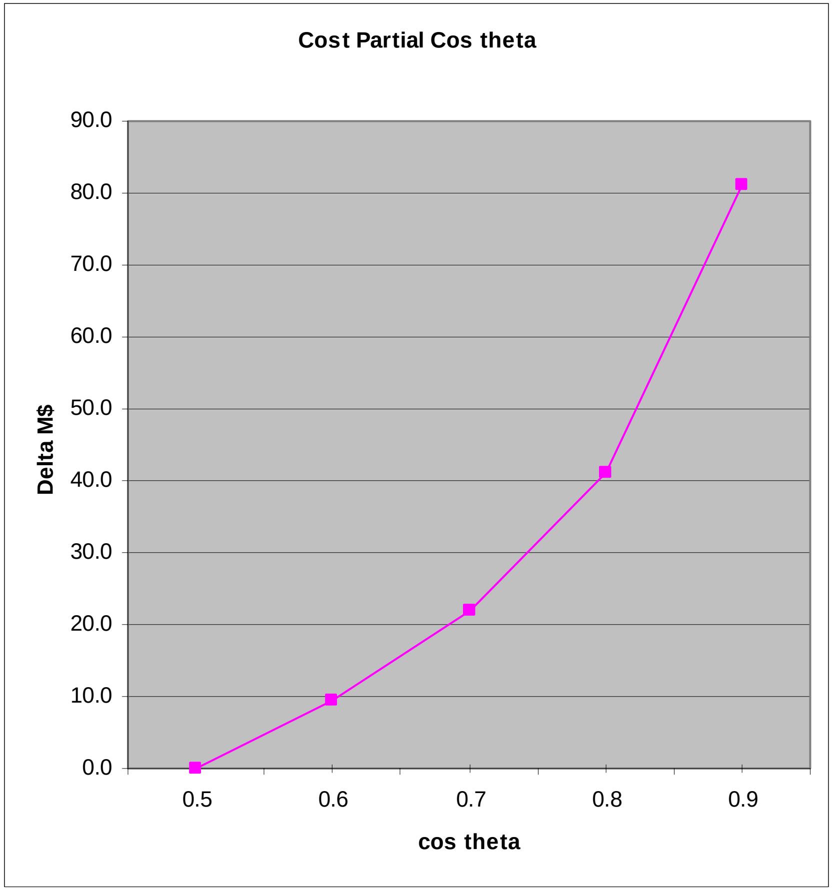
Coil and Iron

- Solenoid field is 5T
- Coil concept based on CMS 4T design. 4 layers of superconductor about 72 x 22 mm, with pure aluminum stabilizer and aluminum alloy structure.
- Coil Δr about 85 cm
- Stored energy about 1.7 GJ (for Tracker Cone design, R_Trkr=1.25m, $\cos\theta_{barrel}$=0.8). (TESLA is about 2.4 GJ)
- Flux return designed to return the flux! Saturation field assumed to be 1.8 T, perhaps optimistic.
- Iron made of 5 cm slabs with 1.5 cm gaps for detectors, again "reliable" RPC's

SD Δcost vs Tracker Radius



SD Δcost vs Cosθ_{barrel}



SLAC WBS (A. Johnson)

File Edit WBS View Help

WBS | Materials | Labor Rates

WBS	Component	Number	Unit	Materials	MContingency	Labor	LContingency
1	NLC Detectors	1	each	167,571,805	60,840,852	50,069,491	16,201,420
1.1	Silicon Detector	1	each	167,571,805	60,840,852	50,069,491	16,201,420
1.1.1	Vertex Detector	1	each	4,000,000	2,000,000	0	0
1.1.2	Tracker	1	each	8,710,000	4,055,000	3,769,800	1,537,620
1.1.3	Calorimeters	1	each	48,419,740	32,509,948	7,903,250	3,257,065
1.1.4	Muon Tracker	1	each	16,000,000	4,800,000	0	0
1.1.5	Electronics	1	each	16,521,320	3,845,330	21,639,330	6,457,926
1.1.6	Magnet	1	each	70,381,945	12,936,554	5,230,361	1,776,132
1.1.7	Installation	1	each	2,617,800	522,320	4,746,050	1,677,383
1.1.8	Management	1	each	921,000	171,700	6,780,700	1,495,295

Extraordinarily Preliminary Cost Estimate

- Based on L,S, and P costing + driver costs…
- M&S $168M
- Labor 50M
- Contingency 77M

- Total 295M

Conclusions

- Just a beginning
  - ~No simulation
  - Very little discussion
- Roughly consistent design.
  - Small tracker still yields big detector
  - Even with 4m L*, last quad will be in detector
- Lots of opportunities for work and even ideas for hardware R&D